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WATER STANDARDS AND STUDIES, REPORT #87-1

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INTRODUCTION

The reports listed in this document were prepared by staff of the Water Standards and Studies Section, Environmental Management Services Branch of the Manitoba Department of Environment and Workplace Safety and Health. Each report was distributed by the Department as it became available. Enquiries for copies should be directed to the following:

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MANUSCRIPT REPORTS

REPORT 86-1 Brown, D. J. 1986. Bibliography of Water Standards and Studies Section Publications, 1985. Environmental Management Division. Water Standards and Studies. 10 pp.

SUMMARY

The Water Standards and Studies Section, Environmental Management Services Branch, Manitoba Department of Environment and Workplace Safety and Health produced four manuscript reports, one assessment report, three water quality data reports and six miscellaneous reports and presentations during 1985.

REPORT 86-2 Beck, A. E. 1986. PCB and Pesticide Residues in Fish from the Red River Manitoba: 1978-1983. Environmental Management Division. Water Standards and Studies. 89 pp.

SUMMARY

The Biomonitoring sub-program was established in 1978 in order to provide an early warning system with respect to persistent environmental contaminants and to provide an accurate and current assessment of surface water quality within specific drainage basins. The occurrence of polychlorinated biphenyl (PCB) and organochlorine pesticide residues in fish collected from the Red River during the period 1978-1983 comprised one aspect of the program. This aspect was the focus of the present report.

Specimens of three fish species were collected annually from each of three sites (Emerson, St. Norbert and Selkirk). Samples of fish muscle tissue were analyzed by gas chromatography for three PCB formulations and twelve organochlorine insecticides.

The PCB formulation known as Arochlor 1248 was not reported in any of the samples analyzed. A shift over time was observed as dominance in 1978 moved from Arochlor 1254 to Arochlor 1260 by 1981. Statistically significant negative trends which indicated exponential rates of decline in total PCB residues during the period 1978 to 1983 were also detected in most species. A significant decrease

in total PCB loadings to the Red River watershed was inferred from both the shift in dominance and the negative trends.

Among the organochlorine insecticides, aldrin, dieldrin, endrin and methoxychlor were not detected in any of the samples analyzed. Lindane was detected in only one 1978 specimen. Chlordane was first detected in some 1981 specimens from St. Norbert and Selkirk but became common in 1982 specimens from these sites. It was not detected in any of the 1983 samples.

The dominant member of the DDT group encountered during the present study was p,pDDE, a degradation product of DDT. Also commonly encountered was p,p DDD. The o,p and p,p isomers of DDT and the o,p isomers of DDD and DDE were detected only rarely. Significant trends were not detected in annual mean total DDT residues during the six year term of study.

It was concluded that fish muscle tissue residues of PCB had declined significantly during the period of study and that residues of total DDT were representative of long term background and thus were unlikely to change appreciably in the near future. It was also concluded that fish muscle tissue residues of PCB, total DDT and other organochlorine insecticides included in the study did not exceed existing Canadian guidelines.

REPORT 86-3 Williamson, D. A. 1986. Mercury in Water and Sediments in the Churchill and Nelson Rivers, Manitoba, Canada. Environmental Management Division. Water Standards and Studies. 17 pp.

SUMMARY

Concentrations of extractable mercury in water and total mercury in river and lake surficial bottom sediments were measured in samples collected from areas affected by stream regulation projects in the Churchill and Nelson Rivers. The data base extends from approximately 1977 to 1984 for mercury in water and from 1979 to 1983 for mercury in bottom sediments. This data was generated as part of a routine water quality monitoring activity within the Province of Manitoba.

Most extractable mercury in water observations were below the analytical limit of quantitation (0.02 µg/L). The few exceptions were likely

either influenced by sampling or analytical bias or were representative of the upper percentiles of the normal distribution of extractable mercury in water within this area.

Total mercury concentrations in surficial bottom sediments displayed little apparent change at all sites throughout the duration of the investigation. Similarly, little difference was apparent between the various sites examined within areas affected by the Churchill River diversion, within areas affected by Lake Winnipeg regulation and at one unaffected site.

Report 86-4 Beck, A. E. 1986. Metal and Organochlorine Residues in Fish from Lake Dauphin, Manitoba; 1984. Environmental Management Division. Water Standards and Studies. 40 pp.

SUMMARY

A joint federal-provincial effort to rehabilitate the Lake Dauphin fishery began in 1981. The project's high local profile prompted some concerns regarding chemical residues in fish from Lake Dauphin. Water Standards and Studies Section was informally requested to address the issue.

A total of 127 specimens were collected by field staff of Fisheries and Oceans Canada. The specimens were forwarded to Water Standards and Studies by regional staff of Manitoba Natural Resources. Analyses of specimens were performed by the W. M. Ward Technical Services Laboratory.

Muscle tissue residues of all analytes including arsenic, mercury, PCB and DDT were found not to exceed existing federal limits. Muscle tissue residues of metals such as cadmium, chromium, copper, lead, mercury and nickel compared favourably to levels encountered in pristine northern water bodies such as Gods Lake. However, compared to residues encountered in fish from major rivers of southern Manitoba, residues of arsenic and zinc appeared slightly elevated. This was attributed to normal runoff from the watershed and to the fertility and productivity of Lake Dauphin, respectively.

Residues of PCB were not detected in any of the samples analyzed. Excepting dieldrin, muscle tissue residues of the organochlorines analyzed were lower than residues typically encountered in major rivers of southern Manitoba.

REPORT 86-5. Williamson, D. A. 1986. Rationale Document Supporting Revisions to Manitoba Surface Water Quality Objectives. Environmental Management Division. Water Standards and Studies. 40 pp.

SUMMARY

Surface water quality objectives were developed for application within Manitoba in 1976 in order to assist water quality management activities. These objectives underwent several minor revisions in 1979, then a number of major revisions were proposed in 1983. The revisions proposed in 1983 were circulated widely within Manitoba and Canada in order to solicit constructive criticism. The Clean Environment Commission convened a public hearing in November, 1984 to review the proposed revisions in a public forum and to ensure that all those likely to be affected by the changes had an opportunity to comment. The Clean Environment Commission submitted a report in September, 1985 to the Minister, Manitoba Department of Environment and Workplace Safety and Health discussing the findings of their review. This report contained a number of recommendations, only one of which pertained directly to elements of possible technical deficiency within the proposed revisions. The Clean Environment Commission recommended that these issues be re-examined. The following report discusses these areas of contention.

Additionally, new scientific information has become available such that revisions to the specific objectives for the parameters un-ionized ammonia, arsenic, cadmium, chlorine, chromium, copper, cyanide, lead, and mercury are warranted. Rationale is provided to support changes to the objectives for these materials. Minor changes are also warranted to the bacteriological indicator organism objectives for recreational waters. A discussion is included regarding the applicability to Manitoba of recent changes to the recreational water quality criteria in the United States.

Overall, the objectives for these parameters are less restrictive than previously recommended, while providing the same degree of protection as previously envisaged.

Future revisions will continue to be proposed to the Manitoba Surface Water Quality Objectives as more experience is gained and as new scientific information becomes available.

REPORT 86-6 Goldsborough, L. G. and D. J. Brown. 1986. Effects of Aerial Spraying of Forestry Herbicides on Aquatic Ecosystems. Part I. Procedures manual for project #803. Environmental Management Division. Water Standards and Studies. 29 pp.

SUMMARY

A three-year study was initiated to study some effects of herbicides used in silvicultural practice in the southeastern boreal forest of Manitoba on the productivity of adjacent aquatic ecosystems. The objective of the first year of the project (1985) was to select several ponds in this area and quantify underlying differences in physical, chemical and biological parameters. The responses of specific plant communities in ponds later exposed to experimental herbicide additions would be compared to those of unperturbed control ponds, and to baseline data for each pond.

This report summarizes the rationale used in selection of the study ponds, and describes the methods used to evaluate pond morphometry, chemistry and physics of water and sediments, and macrophyte, phytoplankton and periphyton productivity and biomass.

REPORT 86-7 Beck, A. E. 1986. Trophic Study of Gull Lake (50°25', 96°31'). Environmental Management Division. Water Standards and Studies. 78 pp.

SUMMARY

Recreationers at Gull Lake in south-eastern Manitoba (50° 25', 96° 31') have long been concerned with water quality problems. Historical concerns were primarily focused upon occasional fish die-offs, whereas more recent concerns have focused upon the excessive proliferation of aquatic macrophytes and possible bacterial contamination of swimming areas. The present report primarily addresses the issue of the macrophyte problem.

Prior extensive commitments precluded a detailed field investigation of the Gull Lake situation by Water Standards and Studies staff. Accordingly, the Gull Lake Ratepayers Association executive proposed to collect the required field samples according to Water Standards and Studies

guidelines and also to provide pertinent information as required. This proposal was accepted by Water Standards and Studies and the study undertaken. Because of the nature of the water quality problem (i.e. excessive proliferation of macrophytes) and because of the extensive cottage development around the lake, it was suspected that the issue of aquatic macrophyte proliferation was related to an accelerated rate of eutrophication which had been induced by an excessive nutrient supply. The field study was designed to focus investigation upon this possibility. The Association executive commenced sampling on June 6, 1985 and continued at twice weekly intervals throughout the summer season. Final fall and winter samples were collected by Water Standards and Studies staff.

Upon completion of sample analysis, the first task was to confirm the fundamental precepts of the study. The first step to achieving this task involved examination of the available nutrient supply. Application of theoretical, potential and calculated-observed nitrogen: phosphorus ratios confirmed that phosphorus was the limiting nutrient for growth. This meant that its proportional availability controlled the rate of macrophyte growth. The second step was to assess the trophic status of Gull Lake. Application of Carlson's TSI indices and Vollenweider's scale revealed that Gull Lake was borderline between mesotrophic and eutrophic. This meant that the current problems with excessive macrophytic growth were a forerunner to much more serious problems with blue-green (cyanophyte) algae blooms. The third step, the development of a phosphorus budget, linked the first two steps and confirmed the fundamental study precepts. The phosphorus budget indicated that approximately 64.9% of the total phosphorus loading to Gull Lake was contributed by artificial sources. Primary among these sources were cottages, which accounted for 54.8% of the total supply. Lesser proportions were contributed by permanent residences (7.8%) and a local campground (2.3%).

It was determined that a substantial reduction in the amount of phosphorus supplied to Gull Lake may reverse the trend of accelerated eutrophication. Assuming that all artificial loadings were eliminated by the installation of holding tanks for wastewaters and sewage, Gull Lake

could revert to a trophic status bordering between oligotrophy and mesotrophy. This would be similar to conditions extant prior to extensive recreational development around the lake. Due to sediment storage of nutrients and translocation by the roots of aquatic macrophytes, the process of trophic state reversion was estimated to be a relatively long period of approximately fourteen years.

REPORT 86-8 Playle, R. C. and D. A. Williamson. 1986. Water Chemistry Changes Associated with Hydroelectric Development in Northern Manitoba: the Churchill, Rat, Burntwood and Nelson Rivers. Environmental Management Division. Water Standards and Studies. 50 pp.

SUMMARY

The Churchill River diversion and Lake Winnipeg regulation in northern Manitoba have increased the hydroelectric generating capacity of the Burntwood and Nelson river systems. The diversion has resulted in increased flows and water levels along the Burntwood and lower Nelson rivers and reduced flows in the lower Churchill River. Lake Winnipeg regulation has affected water levels and flows in the upper Nelson River through construction of control structures and channels between the outlet lakes of Lake Winnipeg.

The effects of these projects on water chemistry were investigated by comparing water chemistry data from before mid-1976 with data collected after mid-1976. Mid-1976 was chosen as the comparison date because it approximated the time the projects became operational. Student's t-test was used to determine if differences existed between pre- and post-operational means of twenty water chemistry parameters at ten sites along rivers affected by the projects.

Granville Lake on the Churchill River is upriver of the Churchill River diversion and was used as a reference site. Six parameters showed statistically significant changes at Granville Lake after mid-1976. These changes may have been caused by changes in discharge from Reindeer Lake reservoir in Saskatchewan, or variation in a natural phenomenon such as precipitation.

Water chemistry changes along the path of the diversion were due mainly to flooding and the increased flow of softer Churchill River water. Most of the water chemistry changes at the community of South Indian Lake were a result of the increased flow of Churchill River water past a previously sheltered section of Southern Indian Lake. These changes included a reduction of total coliform bacteria. Turbidity increased significantly because of flooding and erosion in Southern Indian Lake. Water chemistry near the community of Nelson House was relatively stable, a consequence of its location off the main flow of the diversion. However, there was an increase in turbidity which was likely due to flooding. Changes in water chemistry in the Burntwood River at Thompson were mostly due to the increased flow of softer Churchill River water.

At Split Lake, located at the junction of the Burntwood and Nelson rivers, water chemistry changes were due to both the increased flow of softer Churchill River water and changes in the upper Nelson River. Changes included an increase in turbidity and a decrease in conductivity because of the increased flow of turbid, softer water along the Burntwood River. Total organic carbon increased because of an increase in total organic carbon in the upper Nelson River.

Water chemistry changes in the upper Nelson River included increases in turbidity, total organic carbon, and total inorganic carbon. These water chemistry changes may have been due to Lake Winnipeg regulation. The upper Nelson sites examined were Sipiwesk Lake, Cross Lake settlement, and Norway House.

Chemistry in the lower Churchill River changed because of increased turbidity from flooding and erosion in Southern Indian Lake and because local drainage had more influence on water chemistry once most of the Churchill River flow was diverted southward. Lower Churchill River sites examined were Missi Falls and the Churchill water intake.

Changes in drinking water quality were mixed. This was observed at South Indian Lake community where turbidity increased but total coliform bacteria decreased after diversion. All surface waters in Manitoba are susceptible to uncontrolled microbial contamination (i.e. by wildlife) so minimum treatment consisting of disinfection is required prior to human consumption. The bacterial

and turbidity data suggest that additional water treatment is now required for water drawn from all the sites considered, except the Churchill River at Granville Lake and Footprint Lake near Nelson House. However, the data suggest that this additional degree of treatment was warranted at most sites even before development.

Predictions of water chemistry changes caused by the hydroelectric projects were generally good, especially those related to changes in water flow. Some predictions could not be tested because of insufficient data. Continued monitoring of water chemistry is recommended to improve our understanding of the effects of hydroelectric development in northern Canada.

REPORT 86-9 Playle, R. C. 1986. Two Computer Programs for Predicting Phosphorus Concentrations in New Reservoirs. Environmental Management Division. Water Standards and Studies. 48 pp.

SUMMARY

Two computer programs for predicting total phosphorus concentrations in new reservoirs were developed using a published model. Both are written in Basic and are presented in detail. The first program represents a single reservoir and is useful for studying the sensitivity of the model equation to its input parameters. The second program was designed to represent three reservoirs in series, filling simultaneously or consecutively. Each program's limitations, assumptions, and conceptual problems are discussed using Southern Indian Lake, Notigi, and the proposed Wuskwatim reservoirs as examples. The programs are useful for predicting the severity and duration of trophic upsurge due to phosphorus released from flooded land.

REPORT 86-10 Playle, R. C. 1986. Water Quality Data Supplement: Water Chemistry Changes Associated with Hydroelectric Development in Northern Manitoba. The Churchill, Rat Burntwood and Nelson Rivers. Environmental Management Division. Water Standards and Studies. 262 pp.

SUMMARY

Water chemistry data from ten sites along the Churchill, Burntwood, and Nelson rivers were analyzed to assess the effects of the Churchill River Diversion and Lake Winnipeg regulation on water chemistry. Water chemistry data were collected by Manitoba Environment and Workplace Safety and Health between 1972 and 1984. These data were supplemented with Canada Department of Environment and Canada Department of Fisheries and Oceans data for the same sites, when available. Only the Manitoba data are reported in this report. The Manitoba data represent the majority of the data used in the analysis of Playle (1986) and Playle and Williamson (1986).

REPORT 86-11 Goldsborough, L. G. and D. J. Brown. 1986. Effects of Aerial Spraying of Forestry Herbicides on Aquatic Ecosystems. Part II. Baseline Physical and Chemical Characterization. Environmental Management Division. Water Standards and Studies. 129 pp.

SUMMARY

As part of a three-year study examining some potential effects of herbicide use in forest management on adjacent aquatic ecosystems, baseline physical and chemical characteristics of six small ponds (surface area 0.2-0.7 ha, mean depth <1.5 m) located in the southeastern boreal forest near Pine Falls, Manitoba were monitored in 1985. Nine to twelve surficial sediment samples were collected from each pond in late September and analyzed for textural composition and concentrations of sodium, potassium, calcium, magnesium, iron, manganese, sulphate, carbonate, nitrate and phosphate. Salinity, pH and organic matter content of these samples were also determined. Surface (10-15 cm) water samples were collected at weekly intervals from May to October and one date in December. These were analyzed for true color, pH, conductivity, alkalinity and concentrations of sodium, potassium, calcium, magnesium, iron, manganese, chloride, fluoride, sulphate, ammonia-nitrogen, nitrate/nitrite-nitrogen, total Kjeldahl nitrogen, total phosphorus, silica and dissolved organic carbon. Measurements of water

transparency (Secchi depth), air and surface water temperature and water depth at a fixed location in each pond were also made weekly. Climatic data (daily incident light, wind speed and direction, mid-day air temperature, daily minimum and maximum air temperature, relative humidity and daily precipitation) were collected from a station in the Pine Falls townsite.

This report tabulates the 1985 dateset for the six ponds and summarizes temporal and spatial (between ponds) changes in the above parameters.

SPECIAL REPORTS

Williamson, D. A. 1986. Manitoba Surface Water Quality Objectives. Department of Environment and Workplace Safety and Health. Environmental Management Division. Water Standards and Studies. 52 pp.

SUMMARY

The surface waters of Manitoba are used for numerous purposes including domestic consumption, industrial uses and agricultural purposes such as irrigation and livestock watering. In addition, many surface waters are used for recreational pursuits such as swimming, water skiing, boating and the enjoyment of pleasant scenery. Most waters are also inhabited by fish life, amphibians (frogs), reptiles (turtles), aquatic insects and algae. Large forms of wildlife, small furbearing mammals, waterfowl and some birds of prey rely upon surface waters for drinking purposes, habitat and sources of food supplies.

The quality of surface water has the potential to become degraded through many other legitimate but sometimes conflicting uses such as the disposal of industrial and municipal effluents, development of hydroelectrical generating sites and land-use practices such as agriculture and forestry.

In order to achieve harmony between the various uses, surface water quality objectives were developed which define minimum levels of quality for each of the uses that requires protection. The objectives, when not exceeded, will protect an organism, a community of organisms, a prescribed water use, or a designated multiple purpose water use with an adequate degree of safety. Specific objectives have been developed for over eighty substances.

These objectives affect all Manitobans, since if they do not offer adequate protection, surface water quality may become degraded. Conversely, if they are too restrictive, an unnecessary burden may be imposed on taxpayers and industry in order to pay for additional waste treatment facilities.

Surface water quality objectives are primarily used by government agencies, such as the Environmental Management Division and the Clean Environment Commission, in order to assist in developing effluent discharge restrictions for industrial and municipal waste discharges.

Similarly, developers can use these objectives in planning processes. With information on downstream water uses, existing water quality characteristics and stream discharge volumes, predictions can be made regarding the treatment costs likely to be associated with any specific location. Although this is the principal role of surface water quality objectives within Manitoba, they may also be used for other purposes. For example, the objectives may be used to assist in developing strategies to control land-use practices that may have effects on water quality, such as cottage development. The objectives may be used in combination with environmental monitoring programs to assist in assessing the quality of our surface water resources. The objectives may also be used to assist in determining if certain waters are suitable for uses such as irrigation.

If the objectives are exceeded, there is no direct legal recourse to the source of the pollution. However, the Environmental Management Division may conduct the necessary studies in order to determine the cause of the pollution. Should the cause be waste effluents, legislation under the Clean Environment Act may be used in order to provide the necessary protection.

These objectives are intended to apply to conditions in water that are caused by man's activities. Waters may have natural characteristics outside certain objectives. In such cases, the objectives for those characteristics do not apply. However, if a certain parameter exceeds its objective due to natural conditions, it would be unwise to further increase that parameter by man-made activities, unless such additions would not jeopardize any beneficial use as shown through site-specific investigations.

It is important to realize that scientific information is limited on all the possible effects of a pollutant in the environment. New information, however, is continually being reported. Thus, the objectives must be revised periodically in order to include the most recent scientific knowledge. Based upon the available information, these objectives are designed to afford adequate protection without being unreasonably restrictive yet providing an adequate degree of protection. However, while these objectives are appropriate for most applications

within Manitoba, objective modifications may be required at some unique sites. Modifications of objectives could be required for example, to account for the lower or greater sensitivity of resident aquatic species.

Objectives have not been developed for all possible substances that could affect water quality. Manitoba's surface waters could potentially be contaminated with virtually hundreds of substances. These include, for example, agricultural chemicals, or hazardous goods that may be transported through Manitoba. However, given reasonable information that such substances are present, objectives will be developed using the best available scientific information.

Because specific numerical objectives cannot reasonably be developed for every possible chemical, physical or biological parameter, general statements concerning environmental quality are also used to protect water quality. These requirements, although written in general terms, are nevertheless water quality objectives. For example, these may be used to establish effluent limits even though there may be no specific numerical objectives applicable in the receiving water. General statements have been developed for colour, odour, taste, turbidity, deposits, floating materials, flow, litter, nutrients, oil and grease and toxic substances.

Ideally, objectives should be maintained at all times. It is however, generally accepted that to require objective maintenance at all times is unreasonable. Thus, a specific low flow level has been chosen below which the objectives do not have to be met. This flow, for large streams and rivers, is the lowest flow which, on a statistical basis, would occur for a seven consecutive day period once every ten years. For small intermittent streams this minimum flow is 0.003 m^3/s. However, the flows in many streams in southern Manitoba are regulated by control structures. The minimum flows for these streams are often determined based upon the operating policy of the Water Resources Branch, Department of Natural Resources. The objectives should be maintained at all times in lakes.

Mixing zones are areas adjacent, for example, to a discharge, where the stream or lake may not meet all the water quality objectives. This is allowed for practical reasons, since for most

contaminants, it would be unreasonable to expect the objectives to be met at the end of the discharge pipe. Mixing zones are therefore recognized as areas subject to a loss of value, but nevertheless, certain guidelines should be followed to ensure that the loss is kept as small as possible. These include, for example, ensuring that the entire width of rivers are not completely influenced by a discharge in such a manner that fish movement is prohibited or that bathing areas are not included in mixing zones.

Certain pristine waters support important major uses, such as recreation on surface waters within Provincial Parks. These waters may be given a "High Quality" designation. It is the intent that discharges or other activities that may affect the water quality of these areas should be very strictly controlled. Thus, development within "High Quality" surface water areas will likely be more costly than in other areas of the Province, since all available measures should be used to control environmental disturbances.

Some pristine waters of the Province may be preserved in their natural state for the future. These waters may be given an "Exceptional Value" designation. Development of any type that may affect water quality should be discouraged from these areas.

Objectives have been developed for each of the general surface water uses within Manitoba that requires protection. These are designated as classes and include domestic consumption, aquatic life and wildlife, industrial consumption, agricultural consumption, recreation and other uses. Where possible, these general classes are further divided into categories to provide protection, for example, to the different types of recreation.

CLASS 1: DOMESTIC CONSUMPTION defines objectives that will ensure the protection of waters that are used for human consumption after treatment. All surface waters of Manitoba are susceptible to uncontrolled microbiological contamination, for example, by wildlife. Consequently, minimum treatment consisting of disinfection is required for all surface waters prior to consumption. Objectives are included for substances that may have harmful health effects, such as pesticides, toxic metals and radioactive materials and for substances that may present a nuisance to the consumer, such as excessive hardness and iron.

CLASS 2: AQUATIC LIFE AND WILDLIFE will ensure the protection of waters that are inhabited by aquatic life such as fish, amphibians (frogs), reptiles (turtles) and other forms of life including aquatic insects and algae. By ensuring protection of the aquatic communities, protection is indirectly offered to those forms of wildlife that rely upon surface waters for habitat and for food supplies. These include ducks, geese, furbearing mammals such as the muskrat and birds of prey such as the eagle and osprey. Protection is also provided to those animals that use these waters for drinking purposes.

Objectives are included for numerous parameters including dissolved oxygen, toxic metals and pesticides. The presence of dissolved oxygen in water is essential for aquatic life, and the type of aquatic community is dependent to a large extent on the amount of dissolved oxygen present. Toxic metals, such as zinc and cadmium, in small concentrations, can have harmful effects on growth and reproduction, and in large concentrations, can be lethal. Others, such as mercury and PCB's, even though present in small quantities, can slowly bio-accumulate in the tissue of organisms, until higher harmful levels are reached such that the fisheries resource becomes unsuitable for human consumption.

Some metals, such as cadmium, are more or less toxic depending upon the hardness of the water. For this reason, a mathematical equation is used to establish an objective based upon the relationship between toxicity and hardness.

The existence and composition of an aquatic community also depends upon temperature characteristics. An excessive increase in temperature can be harmful by interfering with fish spawning cycles, causing changes in growth and respiration, and causing more heat tolerant species to replace heat sensitive ones. Heat related winter fish kills can occur when a heated discharge is suddenly stopped. Fish that have been attracted to a heated area are suddenly exposed to the cold ambient temperature.

Developing site-specific temperature objectives is complex and time consuming. Therefore, a method is included by which temperature objectives will be developed for specific discharges.

CLASS 2: AQUATIC LIFE AND WILDLIFE is subdivided into two categories in order to provide specific protection to different general groups of aquatic life in Manitoba.

CATEGORY A: COLD WATER AQUATIC LIFE, COOL WATER AQUATIC LIFE AND WILDLIFE defines objectives that will provide protection to all types of aquatic life inhabiting the surface waters of Manitoba, including the protection of wildlife.

CATEGORY B: COOL WATER AQUATIC LIFE AND WILDLIFE defines objectives that will provide protection to cool water aquatic life such as walleye, sauger and pike, including the protection of wildlife. This category, however, will not provide adequate protection to cold water aquatic organisms such as trout and whitefish.

CLASS 3: INDUSTRIAL CONSUMPTION defines objectives that will ensure the protection of waters that are used for industrial purposes. However, objectives will not be developed at present due to the large number of present and potential industrial users, each with different quality requirements for water.

CLASS 4: AGRICULTURAL CONSUMPTION defines objectives that will provide protection to waters used by the market garden and farming industries for irrigation and livestock watering purposes. Objectives are included for parameters, such as sodium, that will protect variously textured soils. Other objectives, such as boron, will protect sensitive plants. In addition, others, for example, fecal coliform bacteria, are included that are intended to protect humans following consumption of raw vegetables irrigated with waters of this class.

This class is subdivided into four categories in order to provide protection to three different general irrigation practices plus to provide protection for livestock watering.

CATEGORY A: GREENHOUSE IRRIGATION defines objectives that will provide protection to waters that are used by the greenhouse industry where such water is the only source of moisture for the greenhouse plants.

CATEGORY B: FIELD CROP IRRIGATION defines objectives that will provide protection to waters that are used to irrigate field crops, where such water is used to supplement natural rainfall.

CATEGORY C: FIELD CROP IRRIGATION defines objectives that will provide protection to waters that are used to irrigate field crops, where such water is used to supplement natural rainfall. These waters, however, may damage certain soil types if used for long periods of time.

CATEGORY D: LIVESTOCK defines objectives that will provide protection to waters that are used by livestock for drinking purposes.

CLASS 5: RECREATION defines objectives that will ensure that surface waters may be safely used for swimming and boating purposes and also may provide for the enjoyment of pleasant scenery. These waters provide outdoor recreational opportunities for both Manitoba residents and for tourists.

This class is further subdivided into two categories in order to provide protection to the different types of water related recreation depending upon the extent of contact with the water.

CATEGORY A: PRIMARY RECREATION defines objectives that will ensure the protection of waters that may be used for purposes such as swimming and water skiing, where contact with the water is an important aspect of the activity.

CATEGORY B: SECONDARY RECREATION defines objectives that will ensure the protection of waters that may be used for purposes such as fishing and boating, where contact with the water is only incidental to the activity.

CLASS 6: OTHER USES: Manitoba's surface waters may be used for other purposes that do not require protection through the establishment of objectives. These include, for example, the disposal of wastes or the generation of hydroelectrical power. Because of social or economic reasons, certain waters may be used only for these uses.

MISCELLANEOUS

Brown, D. J. and A. E. Beck. Lead Concentrations in Aquatic Systems, Manitoba. Paper presented to the Federal Commission on Lead in the Environment. Winnipeg, Manitoba. January 27, 1986.

Williamson, D. A. Velpar-L (Hexazinone) Movement in Sandy Soils. Paper presented at the Forestry Applicators Course held in Winnipeg, Manitoba. February 11, 1986.

Brown, D. J. Introduction to Limnology. Paper presented at the 32nd Annual Water and Waste School, Winnipeg, Manitoba held February 17 - 21, 1986.

Williamson, D. A. Manitoba Water Quality Objectives. Paper presented at the 32nd Annual Water and Waste School; Winnipeg, Manitoba. February 17 - 21, 1986.

Brown, D. J. Water Quality Monitoring in Manitoba. Paper presented to the Chemical Institute of Canada. Symposium on Environmental Monitoring for Manitoba. Winnipeg, Manitoba. April 18, 1986.

Beck, A. E. Trophic Study of Gull Lake. Paper presented to the Gull Lake Ratepayers Association Annual Meeting, Winnipeg, Manitoba. May 12, 1986.

Beck, A. E. Glyphosate Residues in Surface Waters Following Initial MANFOR Field Trials. Paper presented at the The Pas, Manitoba. May 14, 1986.

Beck, A. E. Cottage Carrying Capacity of Twelve lakes in the South Riding Mountain Planning District. Paper presented to the South Riding Mountain Planning District Board. Erickson, Manitoba. June 12, 1986.

Chacko, V. and D. A. Williamson. Water Quality Concerns with Sediments in Manitoba. Paper presented at Environment Canada Workshop on Manitoba Sediment. Winnipeg, Manitoba. November 18-19, 1986.

Brown, D. J. Pesticides/Heavy Metals in Red River Fish. Paper presented to the Fourth Annual Red River Valley International Land and Water Summit Conference. Grand Forks, North Dakota. November 20 - 21, 1986.

Brown, D. J. Manitoba Red River Monitoring. Paper presented to the Fourth Annual Red River Valley International Land and Water Summit Conference. Grand Forks, North Dakota. November 20 - 21, 1986.

Brown, D. J. Water Quality Levels of Manitoba. Paper presented to the Fourth Annual Red River Valley International Land and Water Summit Conference. Grand Forks, North Dakota. November 20 - 21, 1986.